

09/830446

PCT/CA99/00992

24 FEBRUARY 2000 (24.02.00)

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APPLICATION NUMBER: 60/107,034

FILING DATE: November 02, 1998

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TITLE OF THE INVENTION (280 characters max)					
Chlamydia Antigens and Corresponding DNA Fragments and Uses Thereof					
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ENCLOSED APPLICATION PARTS (check all that apply)					
<input checked="" type="checkbox"/> Specification Number of Pages		31		<input type="checkbox"/> Small Entity Statement	
<input checked="" type="checkbox"/> Drawing(s) Number of Sheets		16		<input type="checkbox"/> Other (specify):	
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Respectfully submitted,

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TITLE OF INVENTION

CHLAMYDIA ANTIGENS AND CORRESPONDING DNA FRAGMENTS AND USES THEREOF

FIELD OF INVENTION

5 The present invention relates to *Chlamydia* antigens and corresponding DNA molecules, which can be used in methods to prevent and treat *Chlamydia* infection in mammals, such as humans.

BACKGROUND OF THE INVENTION

10 Chlamydiae are prokaryotes. They exhibit morphologic and structural similarities to gram-negative bacteria including a trilaminar outer membrane, which contains lipopolysaccharide and several membrane proteins that are structurally and functionally analogous to proteins found in *E coli*. They are obligate intra-cellular parasites with a unique biphasic life cycle consisting of a metabolically inactive but infectious extracellular stage and a replicating but non-infectious intracellular stage. The replicative stage of the life-cycle takes place within a membrane-bound inclusion which sequesters the bacteria away from the cytoplasm of the infected host cell.

15 *C. pneumoniae* is a common human pathogen, originally described as the TWAR strain of *Chlamydia psittaci* but subsequently recognised to be a new species. *C. pneumoniae* is antigenically, genetically and morphologically distinct from other chlamydia species (*C. trachomatis*, *C. pecorum* and *C. psittaci*). It shows 10% or less DNA sequence homology with either of *C. trachomatis* or *C. psittaci* and so far appears to consist of only a single strain, TWAR.

20 *C. pneumoniae* is a common cause of community acquired pneumonia, only less frequent than *Streptococcus pneumoniae* and *Mycoplasma pneumoniae* (Ref 1,2). It can also cause upper respiratory tract symptoms and disease, including bronchitis and sinusitis (Ref 1,3,4,5). The great majority of the adult population (over 60%) has antibodies to *C. pneumoniae* (Ref 5), indicating past infection which was unrecognized or asymptomatic.

25 Of considerable importance is the association of atherosclerosis and *C. pneumoniae* infection. There are several epidemiological studies showing a correlation of previous infections with *C. pneumoniae* and heart attacks, coronary artery and carotid artery disease (Ref 6-10). Moreover, the organisms has been detected in atheromas and fatty streaks of the

coronary, carotid, peripheral arteries and aorta (Ref 11-15). Viable *C. pneumoniae* has been recovered from the coronary and carotid artery (Ref 16,17). Furthermore, it has been shown that *C. pneumoniae* can induce changes of atherosclerosis in a rabbit model (Ref 18). Taken together, these results indicate that it is highly probable that *C. pneumoniae* can cause atherosclerosis in humans; though the epidemiological importance of chlamydial atherosclerosis remains to be demonstrated.

A number of recent studies have also indicated an association between *C. pneumoniae* infection and asthma. Infection has been linked to wheezing, asthmatic bronchitis, adult-onset asthma and acute exacerbations of asthma in adults, and small-scale studies have shown that prolonged antibiotic treatment was effective at greatly reducing the severity of the disease in some individuals (Ref 19-24).

In light of these results a protective vaccine against *C. pneumoniae* infection would be of considerable importance. There is not yet an effective vaccine for any human chlamydial infection. Nevertheless, studies with *C. trachomatis* and *C. psittaci* indicate that this is an attainable goal. For example, mice which have recovered from a lung infection with *C. trachomatis* are protected from infertility induced by a subsequent vaginal challenge (Ref 25). Similarly, sheep immunized with inactivated *C. psittaci* were protected from subsequent chlamydial-induced abortions and stillbirths (Ref 26). Protection from chlamydial infections has been associated with Th1 immune responses, particularly the induction of INF γ - producing CD4+ T-cells (Ref 27). The adoptive transfer of CD4+ cell lines or clones to nude or SCID mice conferred protection from challenge or cleared chronic disease (Ref 28,29), and in vivo depletion of CD4+ T cells exacerbated disease post-challenge (Ref 30,31). However, the presence of sufficiently high titres of neutralising antibody at mucosal surfaces can also exert a protective effect (Ref 32).

The extent of antigenic variation within the species *C. pneumoniae* is not well characterised. Serovars of *C. trachomatis* are defined on the basis of antigenic variation in MOMP, but published *C. pneumoniae* MOMP gene sequences show no variation between several diverse isolates of the organism (Ref 33-35). Regions of the protein known to be conserved in other chlamydial MOMPs are conserved in *C. pneumoniae* (Ref 33,34). One study has described a strain of *C. pneumoniae* with a MOMP of greater than usual molecular weight, but the gene for this has not been sequenced (Ref 1). Partial sequences of outer

membrane protein 2 from nine diverse isolates were also found to be invariant (Ref 16). The genes for HSP60 and HSP70 show little variation from other chlamydial species, as would be expected. The gene encoding a 76kDa antigen has been cloned from a single strain of *C. pneumoniae*. It has no significant similarity with other known chlamydial genes (Ref 4).

5 Many antigens recognised by immune sera to *C. pneumoniae* are conserved across all chlamydiae, but 98kDa, 76 kDa and 54 kDa proteins may be *C. pneumoniae*-specific (Ref 2, 4, 36). Immunoblotting of isolates with sera from patients does show variation of blotting patterns between isolates, indicating that serotypes *C. pneumoniae* may exist (Ref 1,16). However, the results are potentially confounded by the infection status of the patients, since
10 immunoblot profiles of a patient's sera change with time post-infection. An assessment of the number and relative frequency of any serotypes, and the defining antigens, is not yet possible.

C. pneumoniae infection usually presents as an acute respiratory disease (i.e., cough, sore throat, hoarseness, and fever; abnormal chest sounds on auscultation). For most patients, the cough persists for 2 to 6 weeks, and recovery is slow. In approximately 10% of these
15 cases, upper respiratory tract infection is followed by bronchitis or pneumonia. Furthermore, during a *C. pneumoniae* epidemic, subsequent co-infection with pneumococcus has been noted in about half of these pneumonia patients, particularly in the infirm and the elderly. As noted above, there is more and more evidence that *C. pneumoniae* infection is also linked to diseases other than respiratory infections.

20 The reservoir for the organism is presumably people. In contrast to *C. psittaci* infections, there is no known bird or animal reservoir. Transmission has not been clearly defined. It may result from direct contact with secretions, from fomites, or from airborne spread. There is a long incubation period, which may last for many months. Based on analysis of epidemics, *C. pneumoniae* appears to spread slowly through a population (case-to-
25 case interval averaging 30 days) because infected persons are inefficient transmitters of the organism. Susceptibility to *C. pneumoniae* is universal. Reinfections occur during adulthood, following the primary infection as a child. *C. pneumoniae* appears to be an endemic disease throughout the world, noteworthy for superimposed intervals of increased incidence (epidemics) that persist for 2 to 3 years. *C. trachomatis* infection does not confer cross-
30 immunity to *C. pneumoniae*. Infections are easily treated with oral antibiotics, tetracycline or

erythromycin (2 g/d, for at least 10 to 14 d). A recently developed drug, azithromycin, is highly effective as a single-dose therapy against chlamydial infections.

In most instances, *C. pneumoniae* infection is often mild and without complications, and up to 90% of infections are subacute or unrecognized. Among children in industrialized countries, infections have been thought to be rare up to the age of 5 y, although a recent study (E Normann et al, Chlamydia pneumoniae in children with acute respiratory tract infections, Acta Paediatrica, 1998, Vol 87, Iss 1, pp 23-27) has reported that many children in this age group show PCR evidence of infection despite being seronegative, and estimates a prevalence of 17-19% in 2-4 y olds. In developing countries, the seroprevalence of *C. pneumoniae* antibodies among young children is elevated, and there are suspicions that *C. pneumoniae* may be an important cause of acute lower respiratory tract disease and mortality for infants and children in tropical regions of the world.

From seroprevalence studies and studies of local epidemics, the initial *C. pneumoniae* infection usually happens between the ages of 5 and 20 y. In the USA, for example, there are estimated to be 30,000 cases of childhood pneumonia each year caused by *C. pneumoniae*. Infections may cluster among groups of children or young adults (e.g., school pupils or military conscripts).

C. pneumoniae causes 10 to 25% of community-acquired lower respiratory tract infections (as reported from Sweden, Italy, Finland; and the USA). During an epidemic, *C. pneumoniae* infection may account for 50 to 60% of the cases of pneumonia. During these periods, also, more episodes of mixed infections with *S. pneumoniae* have been reported. Reinfection during adulthood is common; the clinical presentation tends to be milder. Based on population seroprevalence studies, there tends to be increased exposure with age, which is particularly evident among men. Some investigators have speculated that a persistent, asymptomatic *C. pneumoniae* infection state is common.

In adults of middle age or older, *C. pneumoniae* infection may progress to chronic bronchitis and sinusitis. A study in the USA revealed that the incidence of pneumonia caused by *C. pneumoniae* in persons younger than 60 years is 1 case per 1,000 persons per year; but in the elderly, the disease incidence rose three-fold. *C. pneumoniae* infection rarely leads to hospitalization, except in patients with an underlying illness.

SUMMARY OF THE INVENTION

The present invention provides purified and isolated DNA molecules that encode *Chlamydia* polypeptides designated CPN100622 (SEQ ID No: 1,2), which can be used in methods to prevent, treat, and diagnose *Chlamydia* infection. The encoded polypeptides
5 include polypeptides having the amino acid sequence shown in SEQ ID No:3 and 4. Those skilled in the art will appreciate that the invention also includes DNA molecules that encode mutants and derivatives of such polypeptides, which result from the addition, deletion, or substitution of non-essential amino acids as described herein. The invention also includes RNA molecules corresponding to the DNA molecules of the invention.

10 In addition to the DNA and RNA molecules, the invention includes the corresponding polypeptides and monospecific antibodies that specifically bind to such polypeptides.

20 The present invention has wide application and includes expression cassettes, vectors, and cells transformed or transfected with the polynucleotides of the invention. Accordingly, the present invention provides (i) a method for producing a polypeptide of the invention in a recombinant host system and related expression cassettes, vectors, and transformed or transfected cells; (ii) a live vaccine vector, such as a pox virus, *Salmonella typhimurium*, or *Vibrio cholerae* vector, containing a polynucleotide of the invention, such
25 vaccine vectors being useful for, *e.g.*, preventing and treating *Chlamydia* infection, in combination with a diluent or carrier, and related pharmaceutical compositions and associated therapeutic and/or prophylactic methods; (iii) a therapeutic and/or prophylactic method involving administration of an RNA or DNA molecule of the invention, either in a naked form or formulated with a delivery vehicle, a polypeptide or combination of polypeptides, or a monospecific antibody of the invention, and related pharmaceutical compositions; (iv) a
30 method for diagnosing the presence of *Chlamydia* in a biological sample, which can involve the use of a DNA or RNA molecule, a monospecific antibody, or a polypeptide of the invention; and (v) a method for purifying a polypeptide of the invention by antibody-based affinity chromatography.

BRIEF DESCRIPTION OF THE DRAWINGS

30 The present invention will be further understood from the following description with reference to the drawings, in which:

Figure 1 shows the nucleotide sequence of the CPN100622 (SEQ ID No: 1 - entire sequence and SEQ ID No: 2 - coding sequence) and the deduced amino acid sequence of the CPN100622 protein from *Chlamydia pneumoniae* (SEQ ID No: 3 - full length and 4 - processed).

Figure 2 shows the restriction enzyme analysis of the gene encoding the *C. pneumoniae* CPN100622 gene.

DETAILED DESCRIPTION OF INVENTION

In the *C. pneumoniae* genome, open reading frames (ORFs) encoding chlamydial polypeptides have been identified. These polypeptides include polypeptides permanently found in the bacterial membrane structure, polypeptides that are present in the external vicinity of the bacterial membrane, include polypeptides permanently found in the inclusion membrane structure, polypeptides that are present in the external vicinity of the inclusion membrane, and polypeptides that are released into the cytoplasm of the infected cell. These polypeptides can be used in vaccination methods for preventing and treating *Chlamydia* infection.

According to a first aspect of the invention, there are provided isolated polynucleotides encoding the precursor and mature forms of *Chlamydia* polypeptides.

An isolated polynucleotide of the invention encodes (i) a polypeptide having an amino acid sequence that is homologous to a *Chlamydia* amino acid, the *Chlamydia* amino acid sequence being selected from the group consisting of:

(a) the amino acid sequences as shown (SEQ ID No: 3 and 4)

The term "isolated polynucleotide" is defined as a polynucleotide removed from the environment in which it naturally occurs. For example, a naturally-occurring DNA molecule present in the genome of a living bacteria or as part of a gene bank is not isolated, but the same molecule separated from the remaining part of the bacterial genome, as a result of, e.g., a cloning event (amplification), is isolated. Typically, an isolated DNA molecule is free from DNA regions (e.g., coding regions) with which it is immediately contiguous at the 5' or 3' end, in the naturally occurring genome. Such isolated polynucleotides could be part of a vector or a composition and still be isolated in that such a vector or composition is not part of its natural environment.

A polynucleotide of the invention can be in the form of RNA or DNA (e.g., cDNA, genomic DNA, or synthetic DNA), or modifications or combinations thereof. The

DNA can be double-stranded or single-stranded, and, if single-stranded, can be the coding strand or the non-coding (anti-sense) strand. The sequence that encodes a polypeptide of the invention as shown in SEQ ID NOs: 1 and 2, can be (a) the coding sequence as shown in SEQ ID NOs:2 (b) a ribonucleotide sequence derived by transcription of (a) ; or (c) a different coding sequence; this latter, as a result of the redundancy or degeneracy of the genetic code, encodes the same polypeptides as the DNA molecules of which the nucleotide sequences are illustrated in SEQ ID NOs:1 to 2.

By "polypeptide" or "protein" is meant any chain of amino acids, regardless of length or post-translational modification (*e.g.*, glycosylation or phosphorylation). Both terms are used interchangeably in the present application.

By "homologous amino acid sequence" is meant an amino acid sequence that differs from an amino acid sequence shown in SEQ ID No: 3 or 4, only by one or more conservative amino acid substitutions, or by one or more non-conservative amino acid substitutions, deletions, or additions located at positions at which they do not destroy the specific antigenicity of the polypeptide.

Preferably, such a sequence is at least 75%, more preferably 80%, and most preferably 90% identical to an amino acid sequence shown in SEQ ID No: 3 or 4.

Homologous amino acid sequences include sequences that are identical or substantially identical to an amino acid sequence as shown in SEQ ID No:3 or 4. By "amino acid sequence substantially identical" is meant a sequence that is at least 90%, preferably 95%, more preferably 97%, and most preferably 99% identical to an amino acid sequence of reference and that preferably differs from the sequence of reference, if at all, by a majority of conservative amino acid substitutions.

Conservative amino acid substitutions typically include substitutions among amino acids of the same class. These classes include, for example, amino acids having uncharged polar side chains, such as asparagine, glutamine, serine, threonine, and tyrosine; amino acids having basic side chains, such as lysine, arginine, and histidine; amino acids having acidic side chains, such as aspartic acid and glutamic acid; and amino acids having nonpolar side chains, such as glycine, alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan, and cysteine.

Homology is typically measured using sequence analysis software (e.g., Sequence Analysis Software Package of the Genetics Computer Group, University of Wisconsin Biotechnology Center, 1710 University Avenue, Madison, WI 53705). Similar amino acid sequences are aligned to obtain the maximum degree of homology (i.e., identity). To this end, it may be necessary to artificially introduce gaps into the sequence. Once the optimal alignment has been set up, the degree of homology (i.e., identity) is established by recording all of the positions in which the amino acids of both sequences are identical, relative to the total number of positions.

Homologous polynucleotide sequences are defined in a similar way. Preferably, a homologous sequence is one that is at least 45%, more preferably 60%, and most preferably 85% identical to (i) a coding sequence of SEQ ID NOs:1 and 2.

Polypeptides having a sequence homologous to one of the sequences shown in SEQ ID NO: 3 or 4, include naturally-occurring allelic variants, as well as mutants or any other non-naturally occurring variants that are analogous in terms of antigenicity, to a polypeptide having a sequence as shown in SEQ ID NO: 3 or 4.

As is known in the art, an allelic variant is an alternate form of a polypeptide that is characterized as having a substitution, deletion, or addition of one or more amino acids that does not alter the biological function of the polypeptide. By "biological function" is meant the function of the polypeptide in the cells in which it naturally occurs, even if the function is not necessary for the growth or survival of the cells. For example, the biological function of a porin is to allow the entry into cells of compounds present in the extracellular medium. The biological function is distinct from the antigenic function. A polypeptide can have more than one biological function.

Allelic variants are very common in nature. For example, a bacterial species, e.g., *C. pneumoniae*, is usually represented by a variety of strains that differ from each other by minor allelic variations. Indeed, a polypeptide that fulfills the same biological function in different strains can have an amino acid sequence that is not identical in each of the strains. Such an allelic variation may be equally reflected at the polynucleotide level.

Support for the use of allelic variants of polypeptide antigens comes from, e.g., studies of the *Chlamydial* MOMP antigen. The amino acid sequence of the MOMP varies

from strain to strain, yet cross-strain antibody binding plus neutralization of infectivity occurs, indicating that the MOMP, when used as an immunogen, is tolerant of amino acid variations.

Polynucleotides, *e.g.*, DNA molecules, encoding allelic variants can easily be retrieved by polymerase chain reaction (PCR) amplification of genomic bacterial DNA extracted by conventional methods. This involves the use of synthetic oligonucleotide primers matching upstream and downstream of the 5' and 3' ends of the encoding domain. Suitable primers can be designed according to the nucleotide sequence information provided in SEQ ID NOs:1 and 2. Typically, a primer can consist of 10 to 40, preferably 15 to 25 nucleotides. It may be also advantageous to select primers containing C and G nucleotides in a proportion sufficient to ensure efficient hybridization; *e.g.*, an amount of C and G nucleotides of at least 40%, preferably 50% of the total nucleotide amount.

Useful homologs that do not naturally occur can be designed using known methods for identifying regions of an antigen that are likely to be tolerant of amino acid sequence changes and/or deletions. For example, sequences of the antigen from different species can be compared to identify conserved sequences.

Polypeptide derivatives that are encoded by polynucleotides of the invention include, *e.g.*, fragments, polypeptides having large internal deletions derived from full-length polypeptides, and fusion proteins.

Polypeptide fragments of the invention can be derived from a polypeptide having a sequence homologous to any of the sequences shown in SEQ ID NO: 3 or 4, to the extent that the fragments retain the substantial antigenicity of the parent polypeptide (specific antigenicity). Polypeptide derivatives can also be constructed by large internal deletions that remove a substantial part of the parent polypeptide, while retaining specific antigenicity. Generally, polypeptide derivatives should be about at least 12 amino acids in length to maintain antigenicity. Advantageously, they can be at least 20 amino acids, preferably at least 50 amino acids, more preferably at least 75 amino acids, and most preferably at least 100 amino acids in length.

Useful polypeptide derivatives, *e.g.*, polypeptide fragments, can be designed using computer-assisted analysis of amino acid sequences in order to identify sites in protein antigens having potential as surface-exposed, antigenic regions (Ref 37).

Polypeptide fragments and polypeptides having large internal deletions can be used for revealing epitopes that are otherwise masked in the parent polypeptide and that may be of importance for inducing a protective T cell-dependent immune response. Deletions can also remove immunodominant regions of high variability among strains.

5 It is an accepted practice in the field of immunology to use fragments and variants of protein immunogens as vaccines, as all that is required to induce an immune response to a protein is a small (e.g., 8 to 10 amino acid) immunogenic region of the protein. This has been done for a number of vaccines against pathogens other than *Chlamydia*. For example, short synthetic peptides corresponding to surface-exposed antigens of pathogens such as murine
10 mammary tumor virus, peptide containing 11 amino acids; (Ref 38), Semliki Forest virus, peptide containing 16 amino acids (Ref 39), and canine parvovirus, 2 overlapping peptides, each containing 15 amino acids (Ref 40), have been shown to be effective vaccine antigens against their respective pathogens.

Polynucleotides encoding polypeptide fragments and polypeptides having large
15 internal deletions can be constructed using standard methods (Ref 41), for example, by PCR, including inverse PCR, by restriction enzyme treatment of the cloned DNA molecules, or by the method of Kunkel *et al.* (Ref 42); biological material available at Stratagene.

A polypeptide derivative can also be produced as a fusion polypeptide that contains
20 a polypeptide or a polypeptide derivative of the invention fused, e.g., at the N- or C-terminal end, to any other polypeptide (hereinafter referred to as a peptide tail). Such a product can be easily obtained by translation of a genetic fusion, i.e., a hybrid gene. Vectors for expressing fusion polypeptides are commercially available, such as the pMal-c2 or pMal-p2 systems of New England Biolabs, in which the peptide tail is a maltose binding protein, the glutathione-S-transferase system of Pharmacia, or the His-Tag system available from Novagen. These and
25 other expression systems provide convenient means for further purification of polypeptides and derivatives of the invention.

Another particular example of fusion polypeptides included in invention includes a polypeptide or polypeptide derivative of the invention fused to a polypeptide having adjuvant activity, such as, e.g., subunit B of either cholera toxin or *E. coli* heat-labile toxin. Several
30 possibilities are can be used for achieving fusion. First, the polypeptide of the invention can be fused to the N-, or preferably, to the C-terminal end of the polypeptide having adjuvant

activity. Second, a polypeptide fragment of the invention can be fused within the amino acid sequence of the polypeptide having adjuvant activity.

As stated above, the polynucleotides of the invention encode *Chlamydia* polypeptides in precursor or mature form. They can also encode hybrid precursors containing heterologous signal peptides, which can mature into polypeptides of the invention. By "heterologous signal peptide" is meant a signal peptide that is not found in the naturally-occurring precursor of a polypeptide of the invention.

A polynucleotide of the invention, having a homologous coding sequence, hybridizes, preferably under stringent conditions, to a polynucleotide having a sequence as shown in SEQ ID NOs:1 to 2. Hybridization procedures are, *e.g.*, described in Ausubel *et al.*, (Ref 41), Silhavy *et al.* (Ref 43); Davis *et al.* (ref 44). Important parameters that can be considered for optimizing hybridization conditions are reflected in a formula that allows calculation of a critical value, the melting temperature above which two complementary DNA strands separate from each other (Ref 45). This formula is as follows: $T_m = 81.5 + 0.5 \times (\% G+C) + 1.6 \log (\text{positive ion concentration}) - 0.6 \times (\% \text{ formamide})$. Under appropriate stringency conditions, hybridization temperature (T_h) is approximately 20° to 40°C, 20 to 25°C, or, preferably 30 to 40°C below the calculated T_m . Those skilled in the art will understand that optimal temperature and salt conditions can be readily determined empirically in preliminary experiments using conventional procedures.

For example, stringent conditions can be achieved, both for pre-hybridizing and hybridizing incubations, (i) within 4-16 hours at 42°C, in 6 x SSC containing 50% formamide or (ii) within 4-16 hours at 65°C in an aqueous 6 x SSC solution (1 M NaCl, 0.1 M sodium citrate (pH 7.0)).

For polynucleotides containing 30 to 600 nucleotides, the above formula is used and then is corrected by subtracting (600/polynucleotide size in base pairs). Stringency conditions are defined by a T_h that is 5 to 10°C below T_m .

Hybridization conditions with oligonucleotides shorter than 20-30 bases do not exactly follow the rules set forth above. In such cases, the formula for calculating the T_m is as follows: $T_m = 4 \times (G+C) + 2 (A+T)$. For example, an 18 nucleotide fragment of 50% G+C would have an approximate T_m of 54°C.

A polynucleotide molecule of the invention, containing RNA, DNA, or modifications or combinations thereof, can have various applications. For example, a DNA molecule can be used (i) in a process for producing the encoded polypeptide in a recombinant host system, (ii) in the construction of vaccine vectors such as poxviruses, which are further
 5 used in methods and compositions for preventing and/or treating *Chlamydia* infection, (iii) as a vaccine agent (as well as an RNA molecule), in a naked form or formulated with a delivery vehicle and, (iv) in the construction of attenuated *Chlamydia* strains that can over-express a polynucleotide of the invention or express it in a non-toxic, mutated form.

According to a second aspect of the invention, there is therefore provided (i) an
 10 expression cassette containing a DNA molecule of the invention placed under the control of the elements required for expression, in particular under the control of an appropriate promoter; (ii) an expression vector containing an expression cassette of the invention; (iii) a procaryotic or eucaryotic cell transformed or transfected with an expression cassette and/or vector of the invention, as well as (iv) a process for producing a polypeptide or polypeptide derivative
 15 encoded by a polynucleotide of the invention; which involves culturing a procaryotic or eucaryotic cell transformed or transfected with an expression cassette and/or vector of the invention; under conditions that allow expression of the DNA molecule of the invention and, recovering the encoded polypeptide or polypeptide derivative from the cell culture.

A recombinant expression system can be selected from procaryotic and eucaryotic
 20 hosts. Eucaryotic hosts include yeast cells (*e.g.*, *Saccharomyces cerevisiae* or *Pichia pastoris*), mammalian cells (*e.g.*, COS1, NIH3T3, or JEG3 cells), arthropods cells (*e.g.*, *Spodoptera frugiperda* (SF9) cells), and plant cells. Preferably, a procaryotic host such as *E. coli* is used. Bacterial and eucaryotic cells are available from a number of different sources to those skilled in the art, *e.g.*, the American Type Culture Collection (ATCC; Rockville,
 25 Maryland).

The choice of the expression system depends on the features desired for the expressed polypeptide. For example, it may be useful to produce a polypeptide of the invention in a particular lipidated form or any other form.

The choice of the expression cassette will depend on the host system selected as
 30 well as the features desired for the expressed polypeptide. Typically, an expression cassette includes a promoter that is functional in the selected host system and can be constitutive or

inducible; a ribosome binding site; a start codon (ATG) if necessary, a region encoding a signal peptide, *e.g.*, a lipidation signal peptide; a DNA molecule of the invention; a stop codon; and optionally a 3' terminal region (translation and/or transcription terminator). The signal peptide encoding region is adjacent to the polynucleotide of the invention and placed in proper reading frame. The signal peptide-encoding region can be homologous or heterologous to the DNA molecule encoding the mature polypeptide and can be specific to the secretion apparatus of the host used for expression. The open reading frame constituted by the DNA molecule of the invention, solely or together with the signal peptide, is placed under the control of the promoter so that transcription and translation occur in the host system. Promoters, signal peptide encoding regions are widely known and available to those skilled in the art and includes, for example, the promoter of *Salmonella typhimurium* (and derivatives) that is inducible by arabinose (promoter *araB*) and is functional in Gram-negative bacteria such as *E. coli* (as described in U.S. Patent No. 5,028,530 and in Cagnon *et al.*, (Ref 46); the promoter of the gene of bacteriophage T7 encoding RNA polymerase, that is functional in a number of *E. coli* strains expressing T7 polymerase (described in U.S. Patent No. 4,952,496); OspA lipidation signal peptide; and RlpB lipidation signal peptide (Ref 47).

The expression cassette is typically part of an expression vector, which is selected for its ability to replicate in the chosen expression system. Expression vectors (*e.g.*, plasmids or viral vectors) can be chosen from those described in Pouwels *et al.* (Cloning Vectors: A Laboratory Manual 1985, Supp. 1987). They can be purchased from various commercial sources.

Methods for transforming/transfecting host cells with expression vectors will depend on the host system selected as described in Ausubel *et al.*, (Ref 41).

Upon expression, a recombinant polypeptide of the invention (or a polypeptide derivative) is produced and remains in the intracellular compartment, is secreted/excreted in the extracellular medium or in the periplasmic space, or is embedded in the cellular membrane. The polypeptide can then be recovered in a substantially purified form from the cell extract or from the supernatant after centrifugation of the recombinant cell culture. Typically, the recombinant polypeptide can be purified by antibody-based affinity purification or by any other method that can be readily adapted by a person skilled in the art, such as by genetic fusion to a small affinity binding domain. Antibody-based affinity purification

methods are also available for purifying a polypeptide of the invention extracted from a *Chlamydia* strain. Antibodies useful for purifying by immunoaffinity the polypeptides of the invention can be obtained as described below.

5 A polynucleotide of the invention can also be useful in the vaccine field, *e.g.*, for achieving DNA vaccination. There are two major possibilities, either using a viral or bacterial host as gene delivery vehicle (live vaccine vector) or administering the gene in a free form, *e.g.*, inserted into a plasmid. Therapeutic or prophylactic efficacy of a polynucleotide of the invention can be evaluated as described below.

10 Accordingly, in a third aspect of the invention, there is provided (i) a vaccine vector such as a poxvirus, containing a DNA molecule of the invention, placed under the control of elements required for expression; (ii) a composition of matter containing a vaccine vector of the invention, together with a diluent or carrier; particularly, (iii) a pharmaceutical composition containing a therapeutically or prophylactically effective amount of a vaccine vector of the invention; (iv) a method for inducing an immune response against *Chlamydia* in a mammal (*e.g.*, a human; alternatively, the method can be used in veterinary applications for treating or preventing *Chlamydia* infection of animals, *e.g.*, cats or birds), which involves administering to the mammal an immunogenically effective amount of a vaccine vector of the invention to elicit an immune response, *e.g.*, a protective or therapeutic immune response to *Chlamydia*; and particularly, (v) a method for preventing and/or treating a *Chlamydia* (*e.g.*, *C. trachomatis*, *C. psittaci*, *C. pneumonia*, *C. pecorum*) infection, which involves administering a prophylactic or therapeutic amount of a vaccine vector of the invention to an individual in need. Additionally, the third aspect of the invention encompasses the use of a vaccine vector of the invention in the preparation of a medicament for preventing and/or treating *Chlamydia* infection.

25 A vaccine vector of the invention can express one or several polypeptides or derivatives of the invention, as well as at least one additional *Chlamydia* antigen, fragment, homolog, mutant, or derivative thereof. In addition, it can express a cytokine, such as interleukin-2 (IL-2) or interleukin-12 (IL-12), that enhances the immune response (adjuvant effect). Thus, a vaccine vector can include an additional DNA sequence encoding, *e.g.*, a chlamydial antigen, or a cytokine, placed under the control of elements required for expression in a mammalian cell.

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Alternatively, a composition of the invention can include several vaccine vectors, each of them being capable of expressing a polypeptide or derivative of the invention. A composition can also contain a vaccine vector capable of expressing an additional *Chlamydia* antigen, or a subunit, fragment, homolog, mutant, or derivative thereof; or a cytokine such as IL-2 or IL-12.

In vaccination methods for treating or preventing infection in a mammal, a vaccine vector of the invention can be administered by any conventional route in use in the vaccine field, particularly, to a mucosal (*e.g.*, ocular, intranasal, oral, gastric, pulmonary, intestinal, rectal, vaginal, or urinary tract) surface or *via* the parenteral (*e.g.*, subcutaneous, intradermal, intramuscular, intravenous, or intraperitoneal) route. Preferred routes depend upon the choice of the vaccine vector. The administration can be achieved in a single dose or repeated at intervals. The appropriate dosage depends on various parameters understood by skilled artisans such as the vaccine vector itself, the route of administration or the condition of the mammal to be vaccinated (weight, age and the like).

Live vaccine vectors available in the art include viral vectors such as adenoviruses and poxviruses as well as bacterial vectors, *e.g.*, *Shigella*, *Salmonella*, *Vibrio cholerae*, *Lactobacillus*, Bacille bilié de Calmette-Guérin (BCG), and *Streptococcus*.

An example of an adenovirus vector, as well as a method for constructing an adenovirus vector capable of expressing a DNA molecule of the invention, are described in U.S. Patent No. 4,920,209. Poxvirus vectors that can be used include, *e.g.*, vaccinia and canary pox virus, described in U.S. Patent No. 4,722,848 and U.S. Patent No. 5,364,773, respectively (also see, *e.g.*, Tartaglia *et al.*, Virology (1992) 188:217) for a description of a vaccinia virus vector; and Taylor *et al.*, Vaccine (1995) 13:539 for a reference of a canary pox). Poxvirus vectors capable of expressing a polynucleotide of the invention can be obtained by homologous recombination as described in Kieny *et al.*, Nature (1984) 312:163 so that the polynucleotide of the invention is inserted in the viral genome under appropriate conditions for expression in mammalian cells. Generally, the dose of vaccine viral vector, for therapeutic or prophylactic use, can be of from about 1×10^4 to about 1×10^{11} , advantageously from about 1×10^7 to about 1×10^{10} , preferably of from about 1×10^7 to about 1×10^9 plaque-forming units per kilogram. Preferably, viral vectors are administered parenterally; for example, in 3 doses, 4 weeks apart. Those skilled in the art recognize that it is preferable to

avoid adding a chemical adjuvant to a composition containing a viral vector of the invention and thereby minimizing the immune response to the viral vector itself.

Non-toxicogenic *Vibrio cholerae* mutant strains that are useful as a live oral vaccine are described in Mekalanos *et al.*, Nature (1983) 306:551 and U.S. Patent No. 4,882,278 (strain in which a substantial amount of the coding sequence of each of the two *ctxA* alleles has been deleted so that no functional *cholerae* toxin is produced); WO 92/11354 (strain in which the *irgA* locus is inactivated by mutation; this mutation can be combined in a single strain with *ctxA* mutations); and WO 94/1533 (deletion mutant lacking functional *ctxA* and *attRSI* DNA sequences). These strains can be genetically engineered to express heterologous antigens, as described in WO 94/19482. An effective vaccine dose of a *Vibrio cholerae* strain capable of expressing a polypeptide or polypeptide derivative encoded by a DNA molecule of the invention can contain, *e.g.*, about 1×10^5 to about 1×10^9 , preferably about 1×10^6 to about 1×10^8 viable bacteria in an appropriate volume for the selected route of administration. Preferred routes of administration include all mucosal routes; most preferably, these vectors are administered intranasally or orally.

Attenuated *Salmonella typhimurium* strains, genetically engineered for recombinant expression of heterologous antigens or not, and their use as oral vaccines are described in Nakayama *et al.* (Bio/Technology (1988) 6:693) and WO 92/11361. Preferred routes of administration include all mucosal routes; most preferably, these vectors are administered intranasally or orally.

Others bacterial strains useful as vaccine vectors are described in High *et al.*, EMBO (1992) 11:1991 and Sizemore *et al.*, Science (1995) 270:299 (*Shigella flexneri*); Medaglini *et al.*, Proc. Natl. Acad. Sci. USA (1995) 92:6868 (*Streptococcus gordonii*); and Flynn J.L., Cell. Mol. Biol. (1994) 40 (suppl. D):31, WO 88/6626, WO 90/0594, WO 91/13157, WO 92/1796, and WO 92/21376 (Bacille Calmette Guerin).

In bacterial vectors, polynucleotide of the invention can be inserted into the bacterial genome or can remain in a free state, carried on a plasmid.

An adjuvant can also be added to a composition containing a vaccine bacterial vector. A number of adjuvants are known to those skilled in the art. Preferred adjuvants can be selected from the list provided below.

According to a fourth aspect of the invention, there is also provided (i) a composition of matter containing a polynucleotide of the invention, together with a diluent or carrier; (ii) a pharmaceutical composition containing a therapeutically or prophylactically effective amount of a polynucleotide of the invention; (iii) a method for inducing an immune response against *Chlamydia*, in a mammal, by administering to the mammal, an immunogenically effective amount of a polynucleotide of the invention to elicit an immune response, *e.g.*, a protective immune response to *Chlamydia*; and particularly, (iv) a method for preventing and/or treating a *Chlamydia* (*e.g.*, *C. trachomatis*, *C. psittaci*, *C. pneumoniae*, or *C. pecorum*) infection, by administering a prophylactic or therapeutic amount of a polynucleotide of the invention to an individual in need. Additionally, the fourth aspect of the invention encompasses the use of a polynucleotide of the invention in the preparation of a medicament for preventing and/or treating *Chlamydia* infection. The fourth aspect of the invention preferably includes the use of a DNA molecule placed under conditions for expression in a mammalian cell, *e.g.*, in a plasmid that is unable to replicate in mammalian cells and to substantially integrate in a mammalian genome.

Polynucleotides (DNA or RNA) of the invention can also be administered as such to a mammal for vaccine, *e.g.*, therapeutic or prophylactic, purpose. When a DNA molecule of the invention is used, it can be in the form of a plasmid that is unable to replicate in a mammalian cell and unable to integrate in the mammalian genome. Typically, a DNA molecule is placed under the control of a promoter suitable for expression in a mammalian cell. The promoter can function ubiquitously or tissue-specifically. Examples of non-tissue specific promoters include the early Cytomegalovirus (CMV) promoter (described in U.S. Patent No. 4,168,062) and the Rous Sarcoma Virus promoter (described in Norton & Coffin, *Molec. Cell Biol.* (1985) 5:281). The desmin promoter (Li *et al.*, *Gene* (1989) 78:243, Li & Paulin, *J. Biol. Chem.* (1991) 266:6562 and Li & Paulin, *J. Biol. Chem.* (1993) 268:10403) is tissue-specific and drives expression in muscle cells. More generally, useful vectors are described, *i.a.*, WO 94/21797 and Hartikka *et al.*, *Human Gene Therapy* (1996) 7:1205.

For DNA/RNA vaccination, the polynucleotide of the invention can encode a precursor or a mature form. When it encodes a precursor form, the precursor form can be homologous or heterologous. In the latter case, a eucaryotic leader sequence can be used, such as the leader sequence of the tissue-type plasminogen factor (tPA).

A composition of the invention can contain one or several polynucleotides of the invention. It can also contain at least one additional polynucleotide encoding another *Chlamydia* antigen such as urease subunit A, B, or both; or a fragment, derivative, mutant, or analog thereof. A polynucleotide encoding a cytokine, such as interleukin-2 (IL-2) or interleukin-12 (IL-12), can also be added to the composition so that the immune response is enhanced. These additional polynucleotides are placed under appropriate control for expression. Advantageously, DNA molecules of the invention and/or additional DNA molecules to be included in the same composition, can be carried in the same plasmid.

Standard techniques of molecular biology for preparing and purifying polynucleotides can be used in the preparation of polynucleotide therapeutics of the invention. For use as a vaccine, a polynucleotide of the invention can be formulated according to various methods.

First, a polynucleotide can be used in a naked form, free of any delivery vehicles, such as anionic liposomes, cationic lipids, microparticles, e.g., gold microparticles, precipitating agents, e.g., calcium phosphate, or any other transfection facilitating agent. In this case, the polynucleotide can be simply diluted in a physiologically acceptable solution, such as sterile saline or sterile buffered saline, with or without a carrier. When present, the carrier preferably is isotonic, hypotonic, or weakly hypertonic, and has a relatively low ionic strength, such as provided by a sucrose solution, e.g., a solution containing 20% sucrose.

Alternatively, a polynucleotide can be associated with agents that assist in cellular uptake. It can be, i.e., (i) complemented with a chemical agent that modifies the cellular permeability, such as bupivacaine (see, e.g., WO 94/16737), (ii) encapsulated into liposomes, or (iii) associated with cationic lipids or silica, gold, or tungsten microparticles.

Anionic and neutral liposomes are well-known in the art (see, e.g., Liposomes: A Practical Approach, RPC New Ed, IRL press (1990), for a detailed description of methods for making liposomes) and are useful for delivering a large range of products, including polynucleotides.

Cationic lipids are also known in the art and are commonly used for gene delivery. Such lipids include LipofectinTM, also known as DOTMA (N-[1-(2,3-dioleoyloxy)propyl]-N,N,N-trimethylammonium chloride), DOTAP (1,2-bis(oleoyloxy)-3-(trimethylammonio)propane), DDAB (dimethyldioctadecylammonium bromide), DOGS

(dioctadecylamidoglycyl spermine) and cholesterol derivatives such as DC-Chol (3 beta-(N-(N',N'-dimethyl aminomethane)-carbamoyl) cholesterol). A description of these cationic lipids can be found in EP 187,702, WO 90/11092, U.S. Patent No. 5,283,185, WO 91/15501, WO 95/26356, and U.S. Patent No. 5,527,928. Cationic lipids for gene delivery are
 5 preferably used in association with a neutral lipid such as DOPE (dioleoyl phosphatidylethanolamine), as, for example, described in WO 90/11092.

Other transfection-facilitating compounds can be added to a formulation containing cationic liposomes. A number of them are described in, *e.g.*, WO 93/18759, WO 93/19768, WO 94/25608, and WO 95/2397. They include, *i.a.*, spermine derivatives useful for
 10 facilitating the transport of DNA through the nuclear membrane (see, for example, WO 93/18759) and membrane-permeabilizing compounds such as GALA, Gramicidine S, and cationic bile salts (see, for example, WO 93/19768).

Gold or tungsten microparticles can also be used for gene delivery, as described in WO 91/359, WO 93/17706, and Tang *et al.* (Nature (1992) 356:152). In this case, the
 15 microparticle-coated polynucleotides can be injected *via* intradermal or intraepidermal routes using a needleless injection device ("gene gun"), such as those described in U.S. Patent No. 4,945,050, U.S. Patent No. 5,015,580, and WO 94/24263.

The amount of DNA to be used in a vaccine recipient depends, *e.g.*, on the strength of the promoter used in the DNA construct, the immunogenicity of the expressed gene product, the condition of the mammal intended for administration (*e.g.*, the weight, age, and
 20 general health of the mammal), the mode of administration, and the type of formulation. In general, a therapeutically or prophylactically effective dose from about 1 μ g to about 1 mg, preferably, from about 10 μ g to about 800 μ g and, more preferably, from about 25 μ g to about 250 μ g, can be administered to human adults. The administration can be achieved in a single
 25 dose or repeated at intervals.

The route of administration can be any conventional route used in the vaccine field. As general guidance, a polynucleotide of the invention can be administered *via* a mucosal surface, *e.g.*, an ocular, intranasal, pulmonary, oral, intestinal, rectal, vaginal, and urinary tract surface; or *via* a parenteral route, *e.g.*, by an intravenous, subcutaneous, intraperitoneal,
 30 intradermal, intraepidermal, or intramuscular route. The choice of the administration route will depend on, *e.g.*, the formulation that is selected. A polynucleotide formulated in

association with bupivacaine is advantageously administered into muscles. When a neutral or anionic liposome or a cationic lipid, such as DOTMA or DC-Chol, is used, the formulation can be advantageously injected *via* intravenous, intranasal (aerosolization), intramuscular, intradermal, and subcutaneous routes. A polynucleotide in a naked form can advantageously be administered *via* the intramuscular, intradermal, or sub-cutaneous routes.

Although not absolutely required, such a composition can also contain an adjuvant. If so, a systemic adjuvant that does not require concomitant administration in order to exhibit an adjuvant effect is preferable such as, *e.g.*, QS21, which is described in U.S. Patent No. 5,057,546.

The sequence information provided in the present application enables the design of specific nucleotide probes and primers that can be useful in diagnosis. Accordingly, in a fifth aspect of the invention, there is provided a nucleotide probe or primer having a sequence found in or derived by degeneracy of the genetic code from a sequence shown in SEQ ID NO:1 to 2.

The term "probe" as used in the present application refers to DNA (preferably single stranded) or RNA molecules (or modifications or combinations thereof) that hybridize under the stringent conditions, as defined above, to nucleic acid molecules having sequences homologous to those shown in SEQ ID NOS:1 and 2, or to a complementary or anti-sense sequence. Generally, probes are significantly shorter than full-length sequences shown in SEQ ID NOS:1 and 2; for example, they can contain from about 5 to about 100, preferably from about 10 to about 80 nucleotides. In particular, probes have sequences that are at least 75%, preferably at least 85%, more preferably 95% homologous to a portion of a sequence as shown in SEQ ID NOS:1 and 2 or that are complementary to such sequences. Probes can contain modified bases such as inosine, methyl-5-deoxycytidine, deoxyuridine, dimethylamino-5-deoxyuridine, or diamino-2, 6-purine. Sugar or phosphate residues can also be modified or substituted. For example, a deoxyribose residue can be replaced by a polyamide (Nielsen *et al.*, Science (1991) 254:1497) and phosphate residues can be replaced by ester groups such as diphosphate, alkyl, arylphosphonate and phosphorothioate esters. In addition, the 2'-hydroxyl group on ribonucleotides can be modified by including, *e.g.*, alkyl groups.

Probes of the invention can be used in diagnostic tests, as capture or detection probes. Such capture probes can be conventionally immobilized on a solid support, directly or

indirectly, by covalent means or by passive adsorption. A detection probe can be labelled by a detection marker selected from radioactive isotopes; enzymes such as peroxidase, alkaline phosphatase, and enzymes able to hydrolyze a chromogenic, fluorogenic, or luminescent substrate; compounds that are chromogenic, fluorogenic, or luminescent; nucleotide base
 5 analogs; and biotin.

Probes of the invention can be used in any conventional hybridization technique, such as dot blot (Maniatis *et al.*, Molecular Cloning: A Laboratory Manual (1982) Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York), Southern blot (Southern, J. Mol. Biol. (1975) 98:503), northern blot (identical to Southern blot to the exception that RNA
 10 is used as a target), or the sandwich technique (Dunn *et al.*, Cell (1977) 12:23). The latter technique involves the use of a specific capture probe and/or a specific detection probe with nucleotide sequences that at least partially differ from each other.

A primer is usually a probe of about 10 to about 40 nucleotides that is used to initiate enzymatic polymerization of DNA in an amplification process (*e.g.*, PCR), in an
 15 elongation process, or in a reverse transcription method. In a diagnostic method involving PCR, primers can be labelled.

Thus, the invention also encompasses (i) a reagent containing a probe of the invention for detecting and/or identifying the presence of *Chlamydia* in a biological material;
 (ii) a method for detecting and/or identifying the presence of *Chlamydia* in a biological
 20 material, in which (a) a sample is recovered or derived from the biological material, (b) DNA or RNA is extracted from the material and denatured, and (c) exposed to a probe of the invention, for example, a capture, detection probe or both, under stringent hybridization conditions, such that hybridization is detected; and (iii) a method for detecting and/or
 identifying the presence of *Chlamydia* in a biological material, in which (a) a sample is
 25 recovered or derived from the biological material, (b) DNA is extracted therefrom, (c) the extracted DNA is primed with at least one, and preferably two, primers of the invention and amplified by polymerase chain reaction, and (d) the amplified DNA fragment is produced.

As previously mentioned, polypeptides that can be produced upon expression of the newly identified open reading frames are useful vaccine agents.

Therefore, a sixth aspect of the invention features a substantially purified polypeptide or polypeptide derivative having an amino acid sequence encoded by a polynucleotide of the invention.

A "substantially purified polypeptide" is defined as a polypeptide that is separated from the environment in which it naturally occurs and/or that is free of the majority of the polypeptides that are present in the environment in which it was synthesized. For example, a substantially purified polypeptide is free from cytoplasmic polypeptides. Those skilled in the art will understand that the polypeptides of the invention can be purified from a natural source, *i.e.*, a *Chlamydia* strain, or can be produced by recombinant means.

Homologous polypeptides or polypeptide derivatives encoded by polynucleotides of the invention can be screened for specific antigenicity by testing cross-reactivity with an antiserum raised against the polypeptide of reference having an amino acid sequence as shown in SEQ ID NOs:3 to 4. Briefly, a monospecific hyperimmune antiserum can be raised against a purified reference polypeptide as such or as a fusion polypeptide, for example, an expression product of MBP, GST, or His-tag systems or a synthetic peptide predicted to be antigenic. The homologous polypeptide or derivative screened for specific antigenicity can be produced as such or as a fusion polypeptide. In this latter case and if the antiserum is also raised against a fusion polypeptide, two different fusion systems are employed. Specific antigenicity can be determined according to a number of methods, including Western blot (Towbin *et al.*, Proc. Natl. Acad. Sci. USA (1979) 76:4350), dot blot, and ELISA, as described below.

In a Western blot assay, the product to be screened, either as a purified preparation or a total *E. coli* extract, is submitted to SDS-Page electrophoresis as described by Laemmli (Nature (1970) 227:680). After transfer to a nitrocellulose membrane, the material is further incubated with the monospecific hyperimmune antiserum diluted in the range of dilutions from about 1:5 to about 1:5000, preferably from about 1:100 to about 1:500. Specific antigenicity is shown once a band corresponding to the product exhibits reactivity at any of the dilutions in the above range.

In an ELISA assay, the product to be screened is preferably used as the coating antigen. A purified preparation is preferred, although a whole cell extract can also be used. Briefly, about 100 μ l of a preparation at about 10 μ g protein/ml are distributed into wells of a 96-well polycarbonate ELISA plate. The plate is incubated for 2 hours at 37°C then overnight

at 4°C. The plate is washed with phosphate buffer saline (PBS) containing 0.05% Tween 20 (PBS/Tween buffer). The wells are saturated with 250 µl PBS containing 1% bovine serum albumin (BSA) to prevent non-specific antibody binding. After 1 hour incubation at 37°C, the plate is washed with PBS/Tween buffer. The antiserum is serially diluted in PBS/Tween
5 buffer containing 0.5% BSA. 100 µl of dilutions are added per well. The plate is incubated for 90 minutes at 37°C, washed and evaluated according to standard procedures. For example, a goat anti-rabbit peroxidase conjugate is added to the wells when specific antibodies were raised in rabbits. Incubation is carried out for 90 minutes at 37°C and the plate is washed. The reaction is developed with the appropriate substrate and the reaction is measured
10 by colorimetry (absorbance measured spectrophotometrically). Under the above experimental conditions, a positive reaction is shown by O.D. values greater than a non immune control serum.

In a dot blot assay, a purified product is preferred, although a whole cell extract can also be used. Briefly, a solution of the product at about 100 µg/ml is serially two-fold
15 diluted in 50 mM Tris-HCl (pH 7.5). 100 µl of each dilution are applied to a nitrocellulose membrane 0.45 µm set in a 96-well dot blot apparatus (Biorad). The buffer is removed by applying vacuum to the system. Wells are washed by addition of 50 mM Tris-HCl (pH 7.5) and the membrane is air-dried. The membrane is saturated in blocking buffer (50 mM Tris-HCl (pH 7.5) 0.15 M NaCl, 10 g/L skim milk) and incubated with an antiserum dilution from
20 about 1:50 to about 1:5000, preferably about 1:500. The reaction is revealed according to standard procedures. For example, a goat anti-rabbit peroxidase conjugate is added to the wells when rabbit antibodies are used. Incubation is carried out 90 minutes at 37°C and the blot is washed. The reaction is developed with the appropriate substrate and stopped. The reaction is measured visually by the appearance of a colored spot, *e.g.*, by colorimetry.
25 Under the above experimental conditions, a positive reaction is shown once a colored spot is associated with a dilution of at least about 1:5, preferably of at least about 1:500.

Therapeutic or prophylactic efficacy of a polypeptide or derivative of the invention can be evaluated as described below.

According to a seventh aspect of the invention, there is provided (i) a composition
30 of matter containing a polypeptide of the invention together with a diluent or carrier; in particular, (ii) a pharmaceutical composition containing a therapeutically or prophylactically

effective amount of a polypeptide of the invention; (iii) a method for inducing an immune response against *Chlamydia* in a mammal, by administering to the mammal an immunogenically effective amount of a polypeptide of the invention to elicit an immune response, *e.g.*, a protective immune response to *Chlamydia*; and particularly, (iv) a method for preventing and/or treating a *Chlamydia* (*e.g.*, *C. trachomatis*, *C. psittaci*, *C. pneumoniae*, or *C. pecorum*) infection, by administering a prophylactic or therapeutic amount of a polypeptide of the invention to an individual in need. Additionally, the seventh aspect of the invention encompasses the use of a polypeptide of the invention in the preparation of a medicament for preventing and/or treating *Chlamydia* infection.

The immunogenic compositions of the invention can be administered by any conventional route in use in the vaccine field, in particular to a mucosal (*e.g.*, ocular, intranasal, pulmonary, oral, gastric, intestinal, rectal, vaginal, or urinary tract) surface or *via* the parenteral (*e.g.*, subcutaneous, intradermal, intramuscular, intravenous, or intraperitoneal) route. The choice of the administration route depends upon a number of parameters, such as the adjuvant associated with the polypeptide. For example, if a mucosal adjuvant is used, the intranasal or oral route will be preferred and if a lipid formulation or an aluminum compound is used, the parenteral route will be preferred. In the latter case, the sub-cutaneous or intramuscular route is most preferred. The choice can also depend upon the nature of the vaccine agent. For example, a polypeptide of the invention fused to CTB or LTB will be best administered to a mucosal surface.

A composition of the invention can contain one or several polypeptides or derivatives of the invention. It can also contain at least one additional *Chlamydia* antigen, or a subunit, fragment, homolog, mutant, or derivative thereof.

For use in a composition of the invention, a polypeptide or derivative thereof can be formulated into or with liposomes, preferably neutral or anionic liposomes, microspheres, ISCOMS, or virus-like-particles (VLPs) to facilitate delivery and/or enhance the immune response. These compounds are readily available to one skilled in the art; for example, see *Liposomes: A Practical Approach (supra)*.

Adjuvants other than liposomes and the like can also be used and are known in the art. A appropriate selection can conventionally be made by those skilled in the art, for example, from the list provided below.

Administration can be achieved in a single dose or repeated as necessary at intervals as can be determined by one skilled in the art. For example, a priming dose can be followed by three booster doses at weekly or monthly intervals. An appropriate dose depends on various parameters including the recipient (*e.g.*, adult or infant), the particular vaccine antigen, the route and frequency of administration, the presence/absence or type of adjuvant, and the desired effect (*e.g.*, protection and/or treatment), as can be determined by one skilled in the art. In general, a vaccine antigen of the invention can be administered by a mucosal route in an amount from about 10 μ g to about 500 mg, preferably from about 1 mg to about 200 mg. For the parenteral route of administration, the dose usually should not exceed about 1 mg, preferably about 100 μ g.

When used as vaccine agents, polynucleotides and polypeptides of the invention can be used sequentially as part of a multistep immunization process. For example, a mammal can be initially primed with a vaccine vector of the invention such as a pox virus, *e.g.*, via the parenteral route, and then boosted twice with the polypeptide encoded by the vaccine vector, *e.g.*, via the mucosal route. In another example, liposomes associated with a polypeptide or derivative of the invention can also be used for priming, with boosting being carried out mucosally using a soluble polypeptide or derivative of the invention in combination with a mucosal adjuvant (*e.g.*, LT).

A polypeptide derivative of the invention is also useful as a diagnostic reagent for detecting the presence of anti-*Chlamydia* antibodies, *e.g.*, in a blood sample. Such polypeptides are about 5 to about 80, preferably about 10 to about 50 amino acids in length and can be labeled or unlabeled, depending upon the diagnostic method. Diagnostic methods involving such a reagent are described below.

Upon expression of a DNA molecule of the invention, a polypeptide or polypeptide derivative is produced and can be purified using known laboratory techniques. For example, the polypeptide or polypeptide derivative can be produced as a fusion protein containing a fused tail that facilitates purification. The fusion product can be used to immunize a small mammal, *e.g.*, a mouse or a rabbit, in order to raise antibodies against the polypeptide or polypeptide derivative (monospecific antibodies). The eighth aspect of the invention thus provides a monospecific antibody that binds to a polypeptide or polypeptide derivative of the invention.

By "monospecific antibody" is meant an antibody that is capable of reacting with a unique naturally-occurring *Chlamydia* polypeptide. An antibody of the invention can be polyclonal or monoclonal. Monospecific antibodies can be recombinant, *e.g.*, chimeric (*e.g.*, constituted by a variable region of murine origin associated with a human constant region), humanized (a human immunoglobulin constant backbone together with hypervariable region of animal, *e.g.*, murine, origin), and/or single chain. Both polyclonal and monospecific antibodies can also be in the form of immunoglobulin fragments, *e.g.*, F(ab)₂ or Fab fragments. The antibodies of the invention can be of any isotype, *e.g.*, IgG or IgA, and polyclonal antibodies can be of a single isotype or can contain a mixture of isotypes.

The antibodies of the invention, which are raised to a polypeptide or polypeptide derivative of the invention, can be produced and identified using standard immunological assays, *e.g.*, Western blot analysis, dot blot assay, or ELISA (see, *e.g.*, Coligan *et al.*, Current Protocols in Immunology (1994) John Wiley & Sons, Inc., New York, NY). The antibodies can be used in diagnostic methods to detect the presence of a *Chlamydia* antigen in a sample, such as a biological sample. The antibodies can also be used in affinity chromatography methods for purifying a polypeptide or polypeptide derivative of the invention. As is discussed further below, such antibodies can be used in prophylactic and therapeutic passive immunization methods.

Accordingly, a ninth aspect of the invention provides (i) a reagent for detecting the presence of *Chlamydia* in a biological sample that contains an antibody, polypeptide, or polypeptide derivative of the invention; and (ii) a diagnostic method for detecting the presence of *Chlamydia* in a biological sample, by contacting the biological sample with an antibody, a polypeptide, or a polypeptide derivative of the invention, such that an immune complex is formed, and by detecting such complex to indicate the presence of *Chlamydia* in the sample or the organism from which the sample is derived.

Those skilled in the art will understand that the immune complex is formed between a component of the sample and the antibody, polypeptide, or polypeptide derivative, whichever is used, and that any unbound material can be removed prior to detecting the complex. As can be easily understood, a polypeptide reagent is useful for detecting the presence of anti-*Chlamydia* antibodies in a sample, *e.g.*, a blood sample, while an antibody of

the invention can be used for screening a sample, such as a gastric extract or biopsy, for the presence of *Chlamydia* polypeptides.

For use in diagnostic applications, the reagent (*i.e.*, the antibody, polypeptide, or polypeptide derivative of the invention) can be in a free state or immobilized on a solid support, such as a tube, a bead, or any other conventional support used in the field. Immobilization can be achieved using direct or indirect means. Direct means include passive adsorption (non-covalent binding) or covalent binding between the support and the reagent. By "indirect means" is meant that an anti-reagent compound that interacts with a reagent is first attached to the solid support. For example, if a polypeptide reagent is used, an antibody that binds to it can serve as an anti-reagent, provided that it binds to an epitope that is not involved in the recognition of antibodies in biological samples. Indirect means can also employ a ligand-receptor system, for example, a molecule such as a vitamin can be grafted onto the polypeptide reagent and the corresponding receptor can be immobilized on the solid phase. This is illustrated by the biotin-streptavidin system. Alternatively, indirect means can be used, *e.g.*, by adding to the reagent a peptide tail, chemically or by genetic engineering, and immobilizing the grafted or fused product by passive adsorption or covalent linkage of the peptide tail.

According to a tenth aspect of the invention, there is provided a process for purifying, from a biological sample, a polypeptide or polypeptide derivative of the invention, which involves carrying out antibody-based affinity chromatography with the biological sample, wherein the antibody is a monospecific antibody of the invention.

For use in a purification process of the invention, the antibody can be polyclonal or monospecific, and preferably is of the IgG type. Purified IgGs can be prepared from an antiserum using standard methods (see, *e.g.*, Coligan *et al.*, *supra*). Conventional chromatography supports, as well as standard methods for grafting antibodies, are disclosed in, *e.g.*, Antibodies: A Laboratory Manual, D. Lane, E. Harlow, Eds. (1988).

Briefly, a biological sample, such as an *C. pneumoniae* extract, preferably in a buffer solution, is applied to a chromatography material, preferably equilibrated with the buffer used to dilute the biological sample so that the polypeptide or polypeptide derivative of the invention (*i.e.*, the antigen) is allowed to adsorb onto the material. The chromatography material, such as a gel or a resin coupled to an antibody of the invention, can be in batch form

or in a column. The unbound components are washed off and the antigen is then eluted with an appropriate elution buffer, such as a glycine buffer or a buffer containing a chaotropic agent, *e.g.*, guanidine HCl, or high salt concentration (*e.g.*, 3 M MgCl₂). Eluted fractions are recovered and the presence of the antigen is detected, *e.g.*, by measuring the absorbance at 280 nm.

An antibody of the invention can be screened for therapeutic efficacy as described as follows. According to an eleventh aspect of the invention, there is provided (i) a composition of matter containing a monospecific antibody of the invention, together with a diluent or carrier; (ii) a pharmaceutical composition containing a therapeutically or prophylactically effective amount of a monospecific antibody of the invention, and (iii) a method for treating or preventing a *Chlamydia* (*e.g.*, *C. trachomatis*, *C. psittaci*, *C. pneumoniae* or *C. pecorum*) infection, by administering a therapeutic or prophylactic amount of a monospecific antibody of the invention to an individual in need. Additionally, the eleventh aspect of the invention encompasses the use of a monospecific antibody of the invention in the preparation of a medicament for treating or preventing *Chlamydia* infection.

To this end, the monospecific antibody can be polyclonal or monoclonal, preferably of the IgA isotype (predominantly). In passive immunization, the antibody can be administered to a mucosal surface of a mammal, *e.g.*, the gastric mucosa, *e.g.*, orally or intragastrically, advantageously, in the presence of a bicarbonate buffer. Alternatively, systemic administration, not requiring a bicarbonate buffer, can be carried out. A monospecific antibody of the invention can be administered as a single active component or as a mixture with at least one monospecific antibody specific for a different *Chlamydia* polypeptide. The amount of antibody and the particular regimen used can be readily determined by one skilled in the art. For example, daily administration of about 100 to 1,000 mg of antibodies over one week, or three doses per day of about 100 to 1,000 mg of antibodies over two or three days, can be an effective regimens for most purposes.

Therapeutic or prophylactic efficacy can be evaluated using standard methods in the art, *e.g.*, by measuring induction of a mucosal immune response or induction of protective and/or therapeutic immunity, using, *e.g.*, the *C. pneumoniae* mouse model. Those skilled in the art will recognize that the *C. pneumoniae* strain of the model can be replaced with another *Chlamydia* strain. For example, the efficacy of DNA molecules and polypeptides from *C.*

pneumoniae is preferably evaluated in a mouse model using an *C. pneumoniae* strain. Protection can be determined by comparing the degree of *Chlamydia* infection to that of a control group. Protection is shown when infection is reduced by comparison to the control group. Such an evaluation can be made for polynucleotides, vaccine vectors, polypeptides and derivatives thereof, as well as antibodies of the invention.

Adjuvants useful in any of the vaccine compositions described above are as follows.

Adjuvants for parenteral administration include aluminum compounds, such as aluminum hydroxide, aluminum phosphate, and aluminum hydroxy phosphate. The antigen can be precipitated with, or adsorbed onto, the aluminum compound according to standard protocols. Other adjuvants, such as RIBI (ImmunoChem, Hamilton, MT), can be used in parenteral administration.

Adjuvants for mucosal administration include bacterial toxins, *e.g.*, the cholera toxin (CT), the *E. coli* heat-labile toxin (LT), the *Clostridium difficile* toxin A and the pertussis toxin (PT), or combinations, subunits, toxoids, or mutants thereof. For example, a purified preparation of native cholera toxin subunit B (CTB) can be of use. Fragments, homologs, derivatives, and fusions to any of these toxins are also suitable, provided that they retain adjuvant activity. Preferably, a mutant having reduced toxicity is used. Suitable mutants are described, *e.g.*, in WO 95/17211 (Arg-7-Lys CT mutant), WO 96/6627 (Arg-192-Gly LT mutant), and WO 95/34323 (Arg-9-Lys and Glu-129-Gly PT mutant). Additional LT mutants that can be used in the methods and compositions of the invention include, *e.g.*, Ser-63-Lys, Ala-69-Gly, Glu-110-Asp, and Glu-112-Asp mutants. Other adjuvants, such as a bacterial monophosphoryl lipid A (MPLA) of, *e.g.*, *E. coli*, *Salmonella minnesota*, *Salmonella typhimurium*, or *Shigella flexneri*; saponins, or polylactide glycolide (PLGA) microspheres, can also be used in mucosal administration.

Adjuvants useful for both mucosal and parenteral administrations include polyphosphazene (WO 95/2415), DC-chol (3 b-(N-(N',N'-dimethyl aminomethane)-carbamoyl) cholesterol; U.S. Patent No. 5,283,185 and WO 96/14831) and QS-21 (WO 88/9336).

Any pharmaceutical composition of the invention, containing a polynucleotide, a polypeptide, a polypeptide derivative, or an antibody of the invention, can be manufactured in a conventional manner. In particular, it can be formulated with a pharmaceutically acceptable

diluent or carrier, *e.g.*, water or a saline solution such as phosphate buffer saline. In general, a diluent or carrier can be selected on the basis of the mode and route of administration, and standard pharmaceutical practice. Suitable pharmaceutical carriers or diluents, as well as pharmaceutical necessities for their use in pharmaceutical formulations, are described in *Remington's Pharmaceutical Sciences*, a standard reference text in this field and in the USP/NF.

The invention also includes methods in which *Chlamydia* infections are treated by oral administration of a *Chlamydia* polypeptide of the invention and a mucosal adjuvant, in combination with an antibiotic, an antacid, sucralfate, or a combination thereof. Examples of such compounds that can be administered with the vaccine antigen and the adjuvant are antibiotics, including, *e.g.*, macrolides, tetracyclines, and derivatives thereof (specific examples of antibiotics that can be used include azithromycin or doxycycline or immunomodulators such as cytokines or steroids. In addition, compounds containing more than one of the above-listed components coupled together, can be used. The invention also includes compositions for carrying out these methods, *i.e.*, compositions containing a *Chlamydia*-antigen (or antigens) of the invention, an adjuvant, and one or more of the above-listed compounds, in a pharmaceutically acceptable carrier or diluent.

Amounts of the above-listed compounds used in the methods and compositions of the invention can readily be determined by one skilled in the art. In addition, one skilled in the art can readily design treatment/immunization schedules. For example, the non-vaccine components can be administered on days 1-14, and the vaccine antigen + adjuvant can be administered on days 7, 14, 21, and 28.

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Figure 1

tctcaagagt aaccttatcc ttagattatt cagctcaagt ctctctgtca actgtaggtc 60

aataccttaa agctgagagt cattgcacat tttaaccaca atg aaa aca tca agg 115
Met Lys Thr Ser Arg
1 5

aat aaa cag tgc aaa ata aca gat ccc tta agt aaa tct tcc ttc ttt 163
Asn Lys Gln Cys Lys Ile Thr Asp Pro Leu Ser Lys Ser Ser Phe Phe
10 15 20

gtt gga gcc tta att tta ggt aaa act aca ata ctc ctt aat gcg act 211
Val Gly Ala Leu Ile Leu Gly Lys Thr Thr Ile Leu Leu Asn Ala Thr
25 30 35

ccg ttg tct gac tat ttt gat aat caa gca aat caa ctc aca aca ctc 259
Pro Leu Ser Asp Tyr Phe Asp Asn Gln Ala Asn Gln Leu Thr Thr Leu
40 45 50

ttc cct cta att gat act ctt act aac atg act ccc tac tct cat aga 307
Phe Pro Leu Ile Asp Thr Leu Thr Asn Met Thr Pro Tyr Ser His Arg
55 60 65

gca aca ctt ttt gga gtt agg gat gac act aac caa gac att gtc ctc 355
Ala Thr Leu Phe Gly Val Arg Asp Asp Thr Asn Gln Asp Ile Val Leu
70 75 80 85

gat cac cag aat tcc ata gaa agc tgg ttc gaa aac ttc tct caa gac 403
Asp His Gln Asn Ser Ile Glu Ser Trp Phe Glu Asn Phe Ser Gln Asp
90 95 100

ggc ggt gct ctc tct tgc aaa tca ctt gcc ata acg aat aca aaa aac 451
Gly Gly Ala Leu Ser Cys Lys Ser Leu Ala Ile Thr Asn Thr Lys Asn
105 110 115

caa att ctt ttc cta aat agc ttt gct att aaa aga gct ggt gcg atg 499
Gln Ile Leu Phe Leu Asn Ser Phe Ala Ile Lys Arg Ala Gly Ala Met
120 125 130

tat gtt gat ggt aat ttc gat ctt tct gag aat cat ggt tcc atc att 547
Tyr Val Asp Gly Asn Phe Asp Leu Ser Glu Asn His Gly Ser Ile Ile
135 140 145

ttc tct ggg aat tta agc ttt cct aat gca agt aat ttc gct gat act 595
Phe Ser Gly Asn Leu Ser Phe Pro Asn Ala Ser Asn Phe Ala Asp Thr
150 155 160 165

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Thr Gly Gly Ala Val Leu Cys Ser Lys Asn Val Thr Ile Ser Lys
170 175 180

aat caa gga acc gca tac ttc att aac aac aag gca aaa tct tca gga 691
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Asn Gln Gly Thr Ala Tyr Phe Ile Asn Asn Lys Ala Lys Ser Ser Gly
185 190 195

gga gca atc caa gct gca atc ata aac att aag gac aac act ggc cct 739
Gly Ala Ile Gln Ala Ala Ile Ile Asn Ile Lys Asp Asn Thr Gly Pro
Gly Ala Ile Gln Ala Ala Ile Ile Asn Ile Lys Asp Asn Thr Gly Pro
200 205 210

tgc ctg ttt ttt aat aat gct gca ggc gga aca gcg ggg ggc gcg ttg 787

Cys Leu Phe Phe Asn Asn Ala Ala Gly Gly Thr Ala Gly Gly Ala Leu
 Cys Leu Phe Phe Asn Asn Ala Ala Gly Gly Thr Ala Gly Gly Ala Leu
 215 220 225

ttc gct aat gct tgt aga att gag aat aat tct cag cct atc tat ttt 835
 Phe Ala Asn Ala Cys Arg Ile Glu Asn Asn Ser Gln Pro Ile Tyr Phe
 Phe Ala Asn Ala Cys Arg Ile Glu Asn Asn Ser Gln Pro Ile Tyr Phe
 230 235 240 245

ttg aat aac caa tca ggt act ggt ggt gca ata aga gta cat caa gag 883
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 Leu Asn Asn Gln Ser Gly Leu Gly Gly Ala Ile Arg Val His Gln Glu
 250 255 260

tgc att ctt aca aag aat acc ggt tct gtg atc ttc aac aat aat ttt 931
 Cys Ile Leu Thr Lys Asn Thr Gly Ser Val Ile Phe Asn Asn Asn Phe
 Cys Ile Leu Thr Lys Asn Thr Gly Ser Val Ile Phe Asn Asn Asn Phe
 265 270 275

gcc atg gaa gcg gac atc tct gct aac cat tcc tct gga ggg gct atc 979
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 Ala Met Glu Ala Asp Ile Ser Ala Asn His Ser Ser Gly Gly Ala Ile
 280 285 290

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 Tyr Cys Ile Ser Cys Ser Ile Lys Asp Asn Pro Gly Ile Ala Ala Phe
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gat aat aat act gca gca gca gat gga ggt gct atc tgc aca caa tct 1075
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 Asp Asn Asn Thr Ala Ala Arg Asp Gly Gly Ala Ile Cys Thr Gln Ser
 310 315 320 325

cta act ata caa gac agt ggt ccc gtc tat ttc aca aac aat cag gga 1123
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 330 335 340

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 Thr Trp Gly Gly Ala Ile Met Leu Arg Gln Asp Gly Ala Cys Thr Leu
 345 350 355

ttt gct gat cag gga gat att att ttt tat aat aat aga cac ttc aaa 1219
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 Phe Ala Asp Gln Gly Asp Ile Ile Phe Tyr Asn Asn Arg His Phe Lys
 360 365 370

gat act ttc agc aat cat gtt tct gta aac tgc acg cgt aat gtc tca 1267
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 Asp Thr Phe Ser Asn His Val Ser Val Asn Cys Thr Arg Asn Val Ser
 375 380 385

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 Leu Thr Val Gly Ala Ser Gln Gly His Ser Ala Thr Phe Tyr Asp Pro
 390 395 400 405

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 Ile Leu Gln Arg Tyr Thr Ile Gln Asn Ser Ile Gln Lys Phe Asn Pro
 410 415 420

aat cca gaa cac ctc gga act atc ttg ttc tcc tca aca tat att ccg 1411
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 Asn Pro Glu His Leu Gly Thr Ile Leu Phe Ser Ser Thr Tyr Ile Pro
 425 430 435

gat aca tcg act tct cgt gat gac ttc att tca cat ttc aga aac cac 1459
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 Asp Thr Ser Thr Ser Arg Asp Asp Phe Ile Ser His Phe Arg Asn His
 440 445 450

att gga ctg tac aac ggc aca ctc gct ctt gaa gat cga gca gag tgg 1507
 Ile Gly Leu Tyr Asn Gly Thr Leu Ala Leu Glu Asp Arg Ala Glu Trp
 Ile Gly Leu Tyr Asn Gly Thr Leu Ala Leu Glu Asp Arg Ala Glu Trp
 455 460 465

aaa gtc tat aaa ttt gat caa ttt ggt ggg act cta cgg tta ggc agt 1555
 Lys Val Tyr Lys Phe Asp Gln Phe Gly Gly Thr Leu Arg Leu Gly Ser
 Gly Val Tyr Lys Phe Asp Gln Phe Gly Gly Thr Leu Arg Leu Gly Ser
 470 475 480 485

aga gct gtg ttt tct aca aca gac gaa gaa caa agt agc agt agt gtg 1603
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 Arg Ala Val Phe Ser Thr Thr Asp Glu Glu Gln Ser Ser Ser Ser Val
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 520 525 530

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 Ser Ala Pro Tyr Ser Glu Asp Asn Asn Pro Ile Ile Asn Leu Ser Gly
 535 540 545

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 Pro Leu Ser Leu Leu Asp Asp Glu Asn Leu Asp Pro Tyr Asp Thr Ala
 550 555 560 565

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 Asp Leu Ala Gln Pro Ile Ala Glu Val Pro Leu Leu Tyr Leu Leu Asp
 570 575 580

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 Val Thr Ala Lys His Ile Asn Thr Asp Asn Phe Tyr Pro Glu Gly Leu
 Val Thr Ala Lys His Ile Asn Thr Asp Asn Phe Tyr Pro Glu Gly Leu
 585 590 595

aat aca act caa cac tac ggc tac caa ggc gtt tgg tcc cct tac tgg 1939
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 Asn Thr Thr Gln His Tyr Gly Tyr Gln Gly Val Trp Ser Pro Tyr Trp
 600 605 610

atc gaa aca atc aca act tct gat acc tct tct gaa gat act gtg aat 1987
 Ile Glu Thr Ile Thr Thr Ser Asp Thr Ser Ser Glu Asp Thr Val Asn
 Ile Glu Thr Ile Thr Thr Ser Asp Thr Ser Ser Glu Asp Thr Val Asn
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 Val Asn Pro Glu Asn Lys Gly Asp Ile Ala Leu Ser Ala Phe Trp Gln
 650 655 660

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 Ser Phe His Asn Leu Phe Ala Thr Leu Arg Tyr Gln Thr Gln Gln Gly
 665 670 675

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 Gln Ile Ala Pro Thr Ala Ser Gly Glu Ala Thr Arg Leu Phe Val His
 Gln Ile Ala Pro Thr Ala Ser Gly Glu Ala Thr Arg Leu Phe Val His
 680 685 690

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 Gln Asn Ser Asn Asn Asp Ala Lys Gly Phe His Met Glu Ala Thr Gly
 695 700 705

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 Tyr Ser Leu Gly Thr Thr Ser Asn Thr Ala Ser Asn His Ser Phe Gly
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gta aac ttc tcc caa ctt ttc agt aat ctc tac gag agc cac tcc gac 2323
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 Val Asn Phe Ser Gln Leu Phe Ser Asn Leu Tyr Glu Ser His Ser Asp
 730 735 740

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 Asn Ser Val Ala Ser His Thr Thr Thr Val Ala Leu Gln Ile Asn Asn
 745 750 755

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 Pro Trp Leu Gln Glu Arg Phe Ser Thr Ser Ala Ser Leu Ala Tyr Ser
 760 765 770

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 Tyr Ser Asn His His Ile Lys Ala Ser Gly Tyr Ser Gly Lys Ile Gln
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 Thr Glu Gly Lys Cys Tyr Ser Thr Thr Leu Gly Ala Ala Leu Ser Cys
 Thr Glu Gly Lys Cys Tyr Ser Thr Thr Leu Gly Ala Ala Leu Ser Cys
 790 795 800 805

tct cta tct cta caa tgg cga tca cga cct ctc cac ctc act cct ttc 2563
 Ser Leu Ser Leu Gln Trp Arg Ser Arg Pro Leu His Phe Thr Pro Phe
 Ser Leu Ser Leu Gln Trp Arg Ser Arg Pro Leu His Phe Thr Pro Phe
 810 815 820

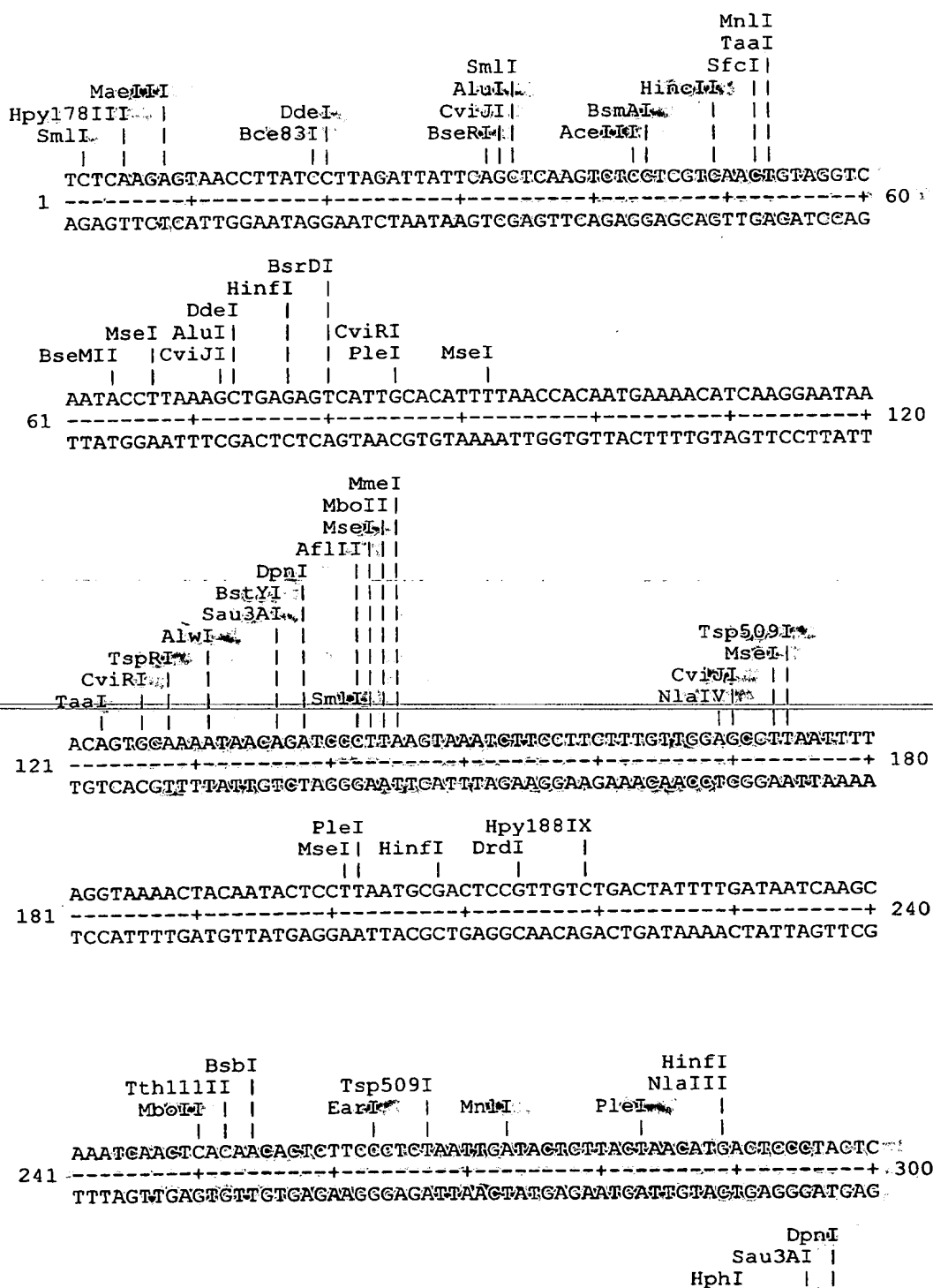
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 Ile Gln Ala Ile Ala Val Arg Ser Asn Gln Thr Ala Phe Gln Glu Ser
 Ile Gln Ala Ile Ala Val Arg Ser Asn Gln Thr Ala Phe Gln Glu Ser

825	830	835	
gga gat aaa gct aga aaa ttt tct gtt cat aaa ccc tta tat aac ctg			2659
Gly Asp Lys Ala Arg Lys Phe Ser Val His Lys Pro Leu Tyr Asn Leu			
Gly Asp Lys Ala Arg Lys Phe Ser Val His Lys Pro Leu Tyr Asn Leu			
840	845	850	
aca gtc cct ctg gga att cag agc gct tgg gaa tcc aag ttc cgt ctt			2707
Thr Val Pro Leu Gly Ile Gln Ser Ala Trp Glu Ser Lys Phe Arg Leu			
Thr Val Pro Leu Gly Ile Gln Ser Ala Trp Glu Ser Lys Phe Arg Leu			
855	860	865	
cct acc tat tgg aac ata gag ctt gct tat cag cct gtc ctc tac caa			2755
Pro Thr Tyr Trp Asn Ile Glu Leu Ala Tyr Gln Pro Val Leu Tyr Gln			
Pro Thr Tyr Trp Asn Ile Glu Leu Ala Tyr Gln Pro Val Leu Tyr Gln			
870	875	880	885
caa aat cct gag atc aac gtg agt cta gaa tct agt gga tcg tca tgg			2803
Gln Asn Pro Glu Ile Asn Val Ser Leu Glu Ser Ser Gly Ser Ser Trp			
Gln Asn Pro Glu Ile Asn Val Ser Leu Glu Ser Ser Gly Ser Ser Trp			
890	895	900	
ctc cta tca gga acc acc ctt gct cgc aat gcc att gct ttt aaa gga			2851
Leu Leu Ser Gly Thr Thr Leu Ala Arg Asn Ala Ile Ala Phe Lys Gly			
Leu Leu Ser Gly Thr Thr Leu Ala Arg Asn Ala Ile Ala Phe Lys Gly			
905	910	915	
aga aac caa att ttt atc ttc cct aaa ctt tcg gtg ttc tta gac tat			2899
Arg Asn Gln Ile Phe Ile Phe Pro Lys Leu Ser Val Phe Leu Asp Tyr			
Arg Asn Gln Ile Phe Ile Phe Pro Lys Leu Ser Val Phe Leu Asp Tyr			
920	925	930	
caa ggc tcg gta tcc tca tca acg acg aca cat tac ctt cac gca gga			2947
Gln Gly Ser Val Ser Ser Ser Thr Thr Thr His Tyr Leu His Ala Gly			
Gln Gly Ser Val Ser Ser Ser Thr Thr Thr His Tyr Leu His Ala Gly			
935	940	945	
acg acc ttt aag ttt taaaagcatg ttatatagac aatgcaacct gtaaagacca			3002
Thr Thr Phe Lys Phe			
Thr Thr Phe Lys Phe			
950			
aatagagagt agtgaacact ctctaccatc atgaatctta tgggagaagc taagggaat			3062
ccacagatac gtttccccca taaaaattaa gaaccgcgata catcctcact agagattcga			3122
aagaactact taaatcctaa gcattcga			3150

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Figure 2

Restriction enzyme analysis of CPN100622



CjeI BsbI CjeI FokI Tth111I | | |
 | | | | | |
 TCATAGAGCAACACTTTTTGGAGTTAGGGATGACACTAACCAAGACATTGTCCTCGATCA
 301 -----+-----+-----+-----+-----+-----+-----+ 360
 AGTATCTCGTTGTGAAAAACCTCAATCCCTACTGTGATTGGTCTGTAAACAGGAGCTAGT

 NspV
 TaqI
 ApoI DrdII |
 EcoRI Bce83I | |
 Tsp509I AluI | | | Hpy178III BsiHKAI Bsp1286I CviRI
 MnlI | CviJI | | | SmlI | AciI | BceFI |
 | | | | | | | | | |
 CCAGAATTCCATAGAAAGCTGGTTCGAAAACCTTCTCTCAAGACGGCGGTGCTCTCTCTTG
 361 -----+-----+-----+-----+-----+-----+-----+ 420
 GGTCTTAAGGTATCTTTTCGACCAAGCTTTTGAAGAGAGTTCTGCCGCCACGAGAGAGAAC

 ApoI AceIII
 Tsp509I AluI |
 | CviJI | MseI
 CAAATCACTTGCCATAACGAATACAAAAACCAAATTCTTTTCTAAATAGCTTTGCTAT
 421 -----+-----+-----+-----+-----+-----+-----+ 480
 GTTTAGTGAACGGTATTGCTTATGTTTTTGGTTTAAGAAAAGGATTTATCGAAACGATA

 HinfI
 DdeI |
 Hpy188IX |
 DpnI |
 Sau3AI |
 BseMII | NlaIV
 AluI Tsp509I | | | | DrdII |
 CviJI BccI | TaqI | | TfiI NlaIII |
 | | | | |
 TAAAAGAGCTGGTGCGATGTATGTTGATGGTAATTCGATCTTTCTGAGAATCATGGTTC
 481 -----+-----+-----+-----+-----+-----+-----+ 540
 ATTTTCTCGACCACGCTACATACAACCTACCATTAAAGCTAGAAAGACTCTTAGTACCAAG

 AluI
 CviJI
 HindIII |
 MseI | |
 BccI ApoI Tsp509I Tsp509I RsaI
 Tsp509I | | | CviRI | BsrGI |
 | | | | | | TatI |
 | | | | | | AceIII |
 CATCATTTTCTCTGGGAATTTAAGCTTTCTAATGCAAGTAATTCGCTGATACTTGTA
 541 -----+-----+-----+-----+-----+-----+-----+ 600
 GTAGTAAAAGAGACCCCTAAATTCGAAAGGATTACGTTTATTAAAGCGACTATGAACATG

 AluI NspV AciI
 CviJI TaqI MaeIII NlaIV |
 | | | |
 AGGGGGAGCTGTTTTATGTTTCGAAAAATGTTACAATCTCAAAAAATCAAGGAACGCATA
 601 -----+-----+-----+-----+-----+-----+-----+ 660
 TCCCCCTCGACAAAATACAAGCTTTTACAATGTTAGAGTTTTTTAGTTCCTTGGCGTAT

40

MnlI | | | MnlI | CviRI | EcoRII | | TseI |
 | | | | | | | | | | | | | | | | | |
 TTCCTCTGGAGGGGCTATCTATTGCATTAGTTGTTCTATAAAAGACAACCCAGGAATTGC
 961 -----+-----+-----+-----+-----+-----+-----+-----+-----+-----+ 1020
 AAGGAGACCTCCCCGATAGATAACGTAATCAACAAGATATTTTCTGTTGGGTCTTAACG

MnlI
 BssSI |
 PstI | |
 Fnu4HI | | |
 CviRI | | | |
 RsaI
 BsrGI |
 TaqI | BbvI | SfcI | | | | BbvI | Hin4I | TatI | BsmFI |
 | | | | | | | | | | | | | | | | | |
 AGCCTTCGATAATAATACTGCAGCAGAGATGGAGGTGCTATCTGTACACAATCTCTAAC
 1021 -----+-----+-----+-----+-----+-----+-----+-----+-----+-----+ 1080
 TCGGAAGCTATTATTATGACGTCGTGCTCTACCTCCACGATAGACATGTGTTAGAGATTG

Sth132I
 BscGI |
 NlaIV | |
 TspRI | |
 AvaII | | |
 Sau96I | | |
 PshAI | | | |
 TaaI | | | |
 HaeII
 Fnu4HI |
 TauI |
 Tth111II | AciI | HhaI |
 | | | |
 TATACAAGACAGTGGTCCGCTCTATTTTACAAACAATCAGGGAAGTGGGGCGGCGCTAT
 1081 -----+-----+-----+-----+-----+-----+-----+-----+-----+-----+ 1140
 ATATGTTCTGTCAACAGGGCAGATAAAGTGTGTTAGTCCCTTGAACCCCGCCGCGATA

CviRI
 NlaIII
 NspI
 SphI
 Cac8I | DpnI
 Hpy178III | CviRI | | BclI |
 NlaIII | BccI | | | Sau3AI |
 | | | | | | | | | |
 CATGCTCCGTCAAGATGGTGCATGCACCTTATTTGCTGATCAGGGAGATATTATTTTAA
 1141 -----+-----+-----+-----+-----+-----+-----+-----+-----+-----+ 1200
 GTACGAGGCAGTTCTACCACGTACGTGAAATAAACGACTAGTCCCTCTATAATAAAAAAT

MmeI
 ThaI
 AflIII |
 Cac8I |
 MluI |
 NlaIII
 BsgI | CviRI | |
 | | | |
 TAATAATAGACACTTCAAAGATACTTTTACGCAATCATGTTTCTGTAAACTGCACGCGTAA
 1201 -----+-----+-----+-----+-----+-----+-----+-----+-----+-----+ 1260
 ATTATTATCTGTGAAGTTTCTATGAAAGTCGTTAGTACAAAGACATTTGACGTGCGCAT

DpnI
 Sau3AI |
 MseI
 BsmAI | TaaI | AlwI | |
 | | | | | |
 TGTCTCATTAAACAGTTGGAGCAAGTCAAGGTCATTCTGCTACCTTCTATGATCCCATACT
 1261 -----+-----+-----+-----+-----+-----+-----+-----+-----+-----+ 1320
 ACAGAGTAATTGTCAACCTCGTTCAGTTCAGTAAGACGATGGAAGATACTAGGGTATGA

CjePI

MseI |
 ApoI | | Hpy188IX
 Tsp509I | | Hpy178III BsaJI |
 ACAAAGATATACTATACAAAACCTCTATCCAAAAATTTAATCCTAATCCAGAACACCTCGG
 1321 -----+-----+-----+-----+-----+-----+-----+-----+ 1380
 TGTTCCTATATGATATGTTTTGAGATAGGTTTTTAAATTAGGATTAGGTCTTGTGGAGCC
 Hpy178III
 MspI |
 BsaWI |
 BspEI |
 MnlI BciVI | | Hpy178III
 BseRI | CjePI MnlI | | TaqI BssSI |
 AACTATCTTGTCTCCTCAACATATATTCGGATACATCGACTTCTCGTGATGACTTCAT
 1381 -----+-----+-----+-----+-----+-----+-----+ 1440
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 TaqI
 DpnI |
 BsrGI | Sau3AI |
 TaaI | BceII |
 Hpy188IX | Hpy178III |
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 1441 -----+-----+-----+-----+-----+-----+-----+ 1500
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 Tsp509I
 DpnI |
 BclI |
 Sau3AI |
 ApoI |
 MboII Tsp509I | | PstI | HinfI |
 AGAGTGGAAAGTCTATAAATTTGATCAATTTGGTGGGACTCTACGGTTAGGCAGTAGAGC
 1501 -----+-----+-----+-----+-----+-----+-----+ 1560
 TCTCACCTTTCAGATATTTAACTAGTTAAACCACCTGAGATGCCAATCCGTCATCTCG
 MboII MseI
 RleAI | Tsp509I |
 TGTGTTTTCTACAACAGACGAAGAACAAGTAGCAGTAGTGTGGGTTCTGTAATTAACAT
 1561 -----+-----+-----+-----+-----+-----+-----+ 1620
 ACACAAAAGATGTTGTCTGCTTCTTGTTCATCGTCATCACACCAAGACATTAATTGTA
 BslI
 PflMI
 MseI
 Tsp509I |
 CviRI |
 MnlI |
 DdeI |
 CAATAATCTTGGCAATTAAGCTTCCCTCTATCTTAGGCAAGACAGTGGTCCCAAGGTATG
 1621 -----+-----+-----+-----+-----+-----+-----+ 1680
 GTTATATAGAACGTTAATTCGAAGGGAGATAGATCCGTTGTCTCAAGGAGGGTTGATAC
 HinfI SfiI
 TfiI RleAI | MboII

| | |
 GATTTCGCCCCACAGGTTTCATCAGCACCTATAGCGAAGATAATAACCCCTATAATCAATCT
 1681 -----+-----+-----+-----+-----+-----+-----+ 1740
 CTAAGCGGGGTGTCCAAGTAGTCGTGGGATATCGCTTCTATTATTGGGATATTAGTTAGA

 AvaII
 Eco0109I
 Psp5II
 Sau96I
 Sse8647I
 Hpy178III | BseMII
 DdeI | | CviJI BsrI AlwI | | |
 | | |
 DpnI
 BstYI |
 Sau3AI |
 BfaI | |
 FokI | |
 | | |
 BstAPI
 PstI |
 CviRI | |
 SfcI | | MwoI
 | | |
 CTCAGGACCTTTGAGCCTACTGGATGACGAGAACCTAGATCCCTATGATACTGCAGACCT
 1741 -----+-----+-----+-----+-----+-----+ 1800
 GAGTCCTGGAAACTCGGATGACCTACTGCTCTTGGATCTAGGGATACTATGACGCTTGGA

 AatII
 MaeIII |
 Tsp45I |
 BsaHI | |
 MnlI MaeII | | AluI MseI
 MboII EarI | DdeI | | CviJI VspI
 | | |
 TGCCCAACCTATCGCAGAAGTTCCTCTTCTGTATCTCTTAGACGTCACAGCTAAACATAT
 1801 -----+-----+-----+-----+-----+-----+ 1860
 ACGGGTTGGATAGCGTCTTCAAGGAGAAGACATAGAGAATCTGCAGTGTGCGATTTGTATA

 MwoI
 BsaJI |
 StyI |
 BseMII Bsu36I
 Tsp509I | MnlI DdeI SimI BsbI CviJI | |
 | | |
 TAATACGGATAATTTCTACCTGAGGGTCTAAATACAACCTCAACACTACGGCTACCAAGG
 1861 -----+-----+-----+-----+-----+-----+ 1920
 ATTATGCCTATTAAAGATGGGACTCCCAGATTTATGTTGAGTTGTGATGCCGATGGTTCC

 TaqI
 NlaIV BsrI
 AvaII | DpnI
 Sau96I | Sau3AI |
 BceFI | | BslI | | AlwI Hpy188IX EarI |
 | | |
 MboII Hpy188IX | |
 | | |
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 1921 -----+-----+-----+-----+-----+-----+ 1980
 GCAAACCCAGGGGAATGACCTAGCTTTGTTAGTGTGAAGACTATGGAGAAGACTTCTATG

 BstXI
 AluI
 MboII CviJI
 TaaI | Eco57I Cac8I | | SfcI
 | | |
 HphI |
 | | |
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 1981 -----+-----+-----+-----+-----+-----+ 2040
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 BsmAI BsrDI MwoI
 | | |
 CCCAGAAAAACAAAGGAGACATTGCCCTATCTGCCTTCTGGCAATCTTTCCATAACTTATT
 2041 -----+-----+-----+-----+-----+-----+ 2100
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Hpy178III
 AlwNI |
 CjeI
 Tth111III |
 CviJI | |
 HaeI | |
 HaeIII | |
 MaeII |
 SfcI | |
 MwoI | |
 CviJI | |
 PleI |
 AluI |
 CviJI |
 2101 TGCGACACTACGTTATCAAACACAGCAAGGCCAAATAGCACCTACAGCTTCTGGAGAAGC 2160
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CjeI
 HinfI | CviRI
 TaqI | | EarI |
 MboII | | BpmI | | SfaNI CjePI HinfI
 XmnI | NdeI | CviJI
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Tth111III
 TspRI |
 MnlI | AluI
 BtsI | CviJI
 CjePI
 BscGI |
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BsaJI
 BstDSI
 Tsp509I |
 Hpy188I |
 CviJI | CviJI
 Pfl1108I | BplI
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HaeIV
 Hin4I
 BbvI |
 DpnI |
 Sau3AI | |
 Hpy178III | |
 HaeII | | |
 HhaI | | |
 Eco47III | | |
 MneI TaaI | | | BsaJI | | Hin4I
 BpmI SfcI | | | StyI TseI | | TfiI
 2341 TACGACAACTGTAGCGCTCCAGATCAATAATCCTTGGCTGCAAGAGAGATTCTCTACATC 2400
 ATGCTGTTGACATCGCGAGGTCTAGTTATTAGGAACCGACGTTCTCTCTAAGAGATGTAG

SfcI
 CviJI |
 SfaNI |
 BfaI | | SfcI
 MwoI | | AluI
 CviRI BplI | | CviJI
 Hpy178III
 SfaNI |
 Hpy178III
 2400 TGCATCTCTAGCCTACAGCTACAGCAACCACCATATCAAAGCATCTGGATATTCTGGAAA

2401 -----+-----+-----+-----+-----+ 2460
ACGTAGAGATCGGATGTCGATGTCGTTGGTGGTATAGTTTCGTAGACCTATAAGACCTTT

CviJI
Fnu4HI |
TauI |
RsaI AciI |
 || |
2461 -----+-----+-----+-----+-----+ 2520
AATACAAACGGAAGGCAAATGTTATAGTACGACATTAGGGGCGGCTCTCTCTTGCTCTCT
TTATGTTTGCCTTCCGTTTACAATATCATGCTGTAATCCCCGCCGAGAGAGAACGAGAGA

BsaXI
Hpy178III |
DpnI | |
Sau3AI | | MnlI BceI MunI
 | | | | Tsp509I
2521 -----+-----+-----+-----+-----+ 2580
ATCTCTACAATGGCGATCAGACCTCTCCACTTCACTCCTTTTATCCAAGCAATTGCCGT
TAGAGATGTTACCGCTAGTGCTGGAGAGGTGAAGTGAGGAAAATAGGTTTCGTTAACGGCA

XmnI
ApoI |
Tsp509I |
BfaI | |
AluI | |
Tth111III Hpy178III CviJI | |
 | | || |
2581 -----+-----+-----+-----+-----+ 2640
TCGTTCTAATCAAACCTGCGTTTCAAGAAAGTGAGATAAAGCTAGAAAATTTTCTGTTCA
AGCAAGATTAGTTTGACGCAAAGTTCTTTCACCTCTATTTCGATCTTTTAAAGACAAGT

HinfI
Bsp24I |
CjePI |
CjeI |
HaeIII |
HhaI | |
Eco47III | | |
Hpy188IX | | | |
MnlI | | | |
ApoI | | | | BbsI
Hin4I EcoRI | | | | MboII
TaaI | Tsp509I | | | | TfiI AhoI
BsmFI | | | |
2641 -----+-----+-----+-----+-----+ 2700
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ATTGCGGAATATATTGGACTGTCAGGGAGACCCTTAAGTCTCGGAACCCTTAGGTTCAA

CjeI Cac8I
CjePI AluI |
Bsp24I | CviJI | CviJI MnlI
 | | | | BseMII |
2701 -----+-----+-----+-----+-----+ 2760
CCGTCTTCCTACCTATTGGAACATAGAGCTTGCTTATCAGCCTGTCTCTACCAACAAA
GGCAGAAGGATGGATAACCTTGTATCTCGAACGAATAGTCGGACAGGAGATGGTTGTTTT

DpnI
Sau3AI |
BfaI | |

PleI | | |
 HinfI | | |
 TfiI | | |
 Hpy178III | | |
 BfaI | | |
 XbaI | | |
 HinfI | | |
 MaeII | | |
 DpnII | | |
 Sau3AI | | |
 DdeI | | |
 Hpy178III | | |
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 2761 -----+----- 2820
 AGGACTCTAGTTGCACTCAGATCTTAGATCACCTAGCAGTACCGAGGATAGTCCTTGGTG
 BsrDI | | | MboII |
 BsrDI | | | DraI | MboII |
 MwoI | | | MseI | ApoI |
 Cac8I | | | CjePI | Tsp509I |
 CCTTGCTCGCAATGCCATTGCTTTTAAAGGAAGAAACCAAATTTTATCTTCCCTAAACT
 2821 -----+----- 2880
 GGAACGAGCGTTACGGTAACGAAAATTCCTTCTTTGGTTTAAAAATAGAAGGGATTGA
 DdeI | | | CviJI | | | MnlI |
 | | | BciVI | | |
 TTCCGTGTTCTTAGACTATCAAGGCTCGGTATCGCTCATCAACGAGGACACATTACCTTCA
 2881 -----+----- 2940
 AAGCCACAAGAAATCTGATAGTTCGGAGGCATAGGAGTAGTTCCTGCTGCTATATGGAAGT
 DraI | | | NlaIII |
 MseI | | | MseI | | | NspI | | | CviRI |
 CGCAGGAACGACGTTTAAGTTTAAAAGCAATGTTATATAGACAATGCAACCTGTAAAGAC
 2941 -----+----- 3000
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 HinfI | | |
 NlaIII | | |
 TfiI | | |
 Hpy178III | | |
 RcaI | | |
 CjePI | | | BccI | | |
 CjePI | | |
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 3001 -----+----- 3060
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 NspV |
 TaqI |
 FokI |
 MseI |
 MaeII | | | Tsp509I | | |
 HinfI | | |
 SphI | | |
 BfaI | | |
 ATCCACAGATACGGTTTCCGCCATAAAATTAAGAACCCGATACATGCTCAGTACGATTC
 3061 -----+----- 3120
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```

          BsmI
        Bpu10I |
      MseI   DdeI |TaqI
        |       |
3121 GAAAGAACTACTTAAATCCTAAGCATTCTGA
-----+-----+-----+ 3150
      CTTTCTTGATGAATTTAGGATTCGTAAGCT
  
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